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Preparing for Flight - The Process of Assessing the ISS Acoustic Environment

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1. INTRODUCTION

In order to promote a safe acoustic environment, processes have been put into place to mitigate the risks of excessive accumulation of acoustic noise within the habitable volumes of the International Space Station (ISS). A safe acoustic environment is one where the crew can communicate effectively and efficiently and hear warning alarms; where the crew can live without being agitated by noise and can rest without being awakened in the middle of the night; and of course, where the crew's auditory organs will not sustain injury. The present paper describes the process that was put in place to control the ISS acoustic environment. This process feeds into the broader ISS Certification of Flight Readiness (CoFR) process, which provides comprehensively for the safety of the crew.

The ISS is a complicated and sophisticated machine, with hundreds of persons dedicated to designing and building hardware, scheduling and preparing for activities and experiments, and overseeing the quality and safety of the entire operation. Since each piece of hardware within the crew's living volume has a possible impact on the noise in the volume, then it is clear that control of the accumulated acoustic noise within the station is the responsibility of many individuals who must be coordinated in their efforts to control the noise. ISS hardware is divided into categories; the module (or vehicle), government furnished equipment (GFE), and payloads. The module and GFE are the hardware that is required to support the crew on the ISS. Payloads are the hardware that facilitate the science experiments, the performance of which are the main purpose for the ISS.

The Johnson Space Center's Acoustics Office works to coordinate the acoustics activities, along with several other organizations, in order to implement the noise control process for the ISS. The Acoustic Working Group (AWG) acts as an advisory committee and is chaired by the Lead of the Acoustics Office. The members of the AWG include representatives from the Acoustics Office and other disciplines, as will be discussed below. Some of the other organizations that are involved will also be discussed.

The first component of the acoustic noise control process for the ISS is through the development and establishment of a set of synergistic acoustic requirements that limit acoustic emissions from the varying levels of hardware in order to achieve an overall satisfactory result. The second component of control is to ensure implementation of these requirements by assisting the hardware developer with quiet design, noise control plan and other acoustic consultation. This second component will not be discussed in the present paper, but is a major portion of the work performed by the Acoustics Office in order to avoid non-compliant situations. This work is discussed in the companion paper by Goodman [1] also presented at this conference. The third component of control is the verification and certification of the flight hardware against the requirements, and the implementation of remedial actions or operational constraints to help the hardware meet requirements or come close to meeting them. This third component also includes the integration and prediction of acoustic levels to satisfy certain requirements as will be discussed, below. The final component of the noise control process is with the measurement of the actual acoustic levels on the ISS. This final step ensures the safety of the crew and is also used as input to the acoustic integration and prediction process. The present paper describes the ISS noise control process, its documentation, and the responsibilities of the groups who implement the process.

2. ISS ACOUSTIC REQUIREMENTS

The first step in the noise control process for ISS is the development and implementation of acoustic emissions requirements to which the flight hardware must comply. As these requirements are described in great detail in the ISS requirements documents, they will only be briefly described, herein. Also, for additional information, the reader is referred to the companion paper by Goodman.[1]

The acoustic requirements and the roll-up of the component acoustic requirements are different for the Russian Segment as compared to the U. S. and other International Partner (IP) Segments. The Russian Segment Specification will only be briefly discussed. Most of the discussion will focus on the U.S. and other IP Segment requirements. The requirements for these segments are based on the U. S. Noise Criterion (NC) family of curves.[2]

The requirements described in the present paper are not to be confused with the requirements regarding mechanical response to high acoustic levels, i.e. as with sonic fatigue. Those requirements are described as “response to acoustic environment” requirements and are out of the scope of this paper.

A. Module Acoustic Requirements

The ISS acoustic requirements for modules and their “integrated government furnished equipment (GFE)” are put forth in the System Specification for the ISS, SSP 41000. This specification states that “the integrated acoustic environment in habitable areas shall not exceed the U. S. NC-50 criterion.”[3] The NC-50 criterion is shown in Figure 1 and in Table 1, and as with all NC family curves, specifies limits for octave band frequency spectra.

The word “integrated” in this requirement was interpreted to mean integrated GFE (such as the air-conditioner), implying that additional (non-integrated) GFE and payloads would not be included as contributors to the levels governed by this requirement. As such, these items are governed by separate requirements as will be discussed, below. For the purposes of this paper, the integrated GFE is considered as part of the module.

The Russian Segment (RS) modules have been granted an exception to the SSP 41000, NC-50 requirement. Instead, the Russian segment acoustic levels are required to meet the requirements specified in the NASA/RSA Joint Specifications, Standards Document for the ISS Russian Segment, SSP 50094. This requirement for continuous noise at work areas is also shown in Figure 1.

With these module requirements all noise sources are treated as continuous noise sources. However, there are exceptions for some intermittent noise sources that were treated on an individual basis, e.g. vacuum exhaust system. Other exceptions and special modifications are out of the scope of this paper but are generally considered in the acoustic environment review and flight certification process.

B. GFE Acoustic Requirements

Non-integrated government furnished equipment items include hardware such as the vacuum cleaner or exercise equipment that are required for the crew or other support yet are not required by the module to perform a necessary module function. The ISS acoustic requirements for non-integrated GFEare defined in

JSC 28322.[4] These requirements specify acoustic emission limits at a 0.6 m (2 ft) distance from the loudest point on the hardware in terms of continuous and intermittent noise.

Continuous noise sources are defined in ISS acoustic specifications as noisemakers that operate for more than 8 hours in any 24-hour period. All other noise sources are classified as intermittent noise sources. The 0.6-meter limit for continuous noise is the NC-40 curve and is given in Figure 1 and Table 1.

The intermittent noise requirements are based on the A-weighted overall sound pressure level, in dBA, and depend on the amount of time in any 24-hour period that the item will generate levels above NC-40. This time is denoted the "maximum duration" for intermittent operations. These intermittent requirements are given in Table 2.

C. Payload Acoustic Requirements

The ISS payload acoustic requirements are specified at several different levels of payload integration. The top-level requirement is specified for the integrated complement of payloads in a module. The complement is made up of isle-mounted payloads and integrated payload racks, which have requirements at this level. Finally, payload racks are made up of sub-rack payloads, which have their own requirements. This requirements break-out is designed to accommodate the number of payloads that need to be managed, and the number of organizations involved. For example, a payload rack facility may be designed and built by one organization, yet several different independent experiments may be developed by different organizations to operate simultaneously inside the rack facility. The requirements described below are designed to provide limits for each organization to satisfy, so that the final integrated result is acceptable.

At the highest level of integration, the continuous noise generated by the total complement of payloads inside a given pressurized module is required to meet the NC-48 criterion. This requirement is specified in the Payload Verification Program Plan, SSP 57011, and is shown in Figure 1 and in Table 1. To satisfy this requirement, the resultant of all continuous payload emissions in a given module is evaluated at the center of the module for compliance. At the present time, the U. S. Destiny Lab is the only module subject to this requirement where payloads are routinely deployed. However, in the future there will be several additional modules in which many payloads will be routinely deployed to which this requirement will apply.

Payloads are routinely deployed in the Russian Segment, though they are not nearly as numerous as those installed in the other segments. The acoustic requirements for these RS payloads are given in SSP 50094, but will not be discussed herein.

The complement of payloads in a given module is made up of payload racks and isle-mounted payloads. According to the Pressurized Payloads Interface Requirements Document, SSP 57000, payload racks and isle-mounted payloads are required to meet the NC-40 and NC-34 criteria, respectively, for continuous noise emissions at a distance of 0.6 m (2 ft) from the loudest point on the hardware. Both of these types of payloads are also subject to intermittent requirements that are the same as those described for non-integrated GFE; see Table 2. The NC-40 and NC-34 curves are shown in Figure 1 and Table 1.

Additional requirements are included in SSP 57000 to limit acoustic levels inside of a rack. These requirements pertain to payload racks where the crewmember's head is required to go into the rack, and are out of the scope of the present paper.

As discussed above, payload racks are sometimes made up of individual experiments, and these are referred to as sub-rack payloads. The acoustic requirements for sub-rack payloads are determined by the payload rack integrator, as the rack integrator is the responsible party for ensuring the integrated rack meets the SSP 57000 requirements. Typically, the rack integrator will determine sub-rack acoustic requirements based on the rack subsystems and the expected sub-rack payloads so that the rack-level requirements will be met. A noise model is typically used to determine these sub-allocations, as will be discussed, below. The EXpedited the PRocessing of Experiments to Space Station (EXPRESS) system of racks requires their sub-rack payloads to meet a modified NC-32 criterion for continuous noise emissions at a 0.6 m (2 ft) distance from the loudest sub-rack payload surface. This modified NC-32 curve is shown in Figure 1 and Table 1.

The sub-rack payloads consist of hardware designed to perform a particular experiment or function. The acoustic requirements for the components of this hardware are the responsibility of the sub-rack payload developer and are out of the scope of this paper. This is the level where it is important to use quiet design principles and an acoustic noise control plan.[1]

3. VERIFICATION OF ACOUSTIC REQUIREMENTS AND PREDICTION OF ON-ORBIT LEVELS

The verification of flight hardware to acoustic noise emissions requirements is performed through actual test measurements of the hardware to the greatest extent possible. However, in many cases acoustic testing of the fully integrated end-item is not possible either because of hardware schedule mismatches or because of physical limitations to the hardware configuration in Earth's gravity. For example, many payload racks are in this situation since the rack facility may already be on the station, but future sub-rack payloads that are to be installed inside that rack are still being developed.

In order to handle these situations, the ground-test measurements may be supplemented by analytical means. In most situations, the analysis is required to be verified by test data resulting in a test-correlated analytical model. These models are used along with the data to verify to acoustic requirements at the various levels of integration.

Remedial actions are performed to quiet hardware that do not meet the appropriate acoustic emission requirements. For a discussion of some of the quieting efforts performed by the Acoustics Office, the reader is referred to the companion paper by Goodman.[1] If an item cannot meet requirements because of cost, schedule, or technical reasons, then a waiver or exception to the requirements must be processed for the piece of flight hardware in question. These non-compliant levels are taken into consideration when predicting the fully integrated acoustic levels in each module.

This section briefly describes the verification process in its simplest form. Slight differences in the process may occur and are justified on an individual basis with the approval of the appropriate organizations. This process is performed for each ISS Stage, which is the period of time the ISS is in a single hardware configuration in regards to module, GFE, or Payload hardware. The Stage is usually denoted by the ISS Flight designation, e.g. UF-1 (Utilization Flight 1) or 6S (sixth Soyuz flight).

A. Module and GFE Noise Contributions

When first launched, modules are verified directly from their compliance data, which is measured during ground verification testing. Once on orbit and fully activated, the module's noise levels are measured as discussed in Section 4, below, and these data are used in future evaluations of flight readiness. Non-integrated GFE are verified directly from ground verification testing.

A module's hardware and resulting noise will not change significantly once activated, and so the ongoing on-orbit acoustic monitoring measurements serve as assurance of crew safety for CoFR for these modules. This monitoring is important in case module hardware deteriorates or malfunctions, causing excessive noise.

B. Payload Noise Contribution

The module's complement of payloads, however, are constantly subject to changing hardware configurations. For example, the U. S. Destiny Lab Module (U. S. Lab) is outfitted with a new complement of payloads for each Stage. Payloads with completed science projects are ferried back to Earth, and new science experiments are delivered to the U. S. Lab for activation and operations.

To accommodate the changing payload hardware situation, a process has been put into place in order to predict the continuous acoustic environment in the U. S. Lab at each Stage. This process consists of a test-correlated analytical model, which was developed by the Payloads Engineering and Integration (PE&I) Office and is implemented in conjunction with the Acoustics Office and Acoustics Working Group (AWG). The result of this analysis is compared with the NC-48 payload complement requirement, discussed in Section 2 above.

While satisfying the payload complement requirement is the final check for payload noise, the control of the actual payload hardware is concentrated at the payload rack level. Payload racks are required to meet the acoustic requirements specified in SSP 57000. These requirements include limits on levels of acoustic emissions categorized in terms of continuous or intermittent types of noise as discussed in Section 2, above. The payload rack integrator is responsible for ensuring that the rack meets these requirements.

Payload racks are divided into two categories, those that will have their sub-rack payloads changed-out over time, and those with fixed hardware configurations. As with the module configuration situation, those racks with a fixed hardware configuration are verified by test directly, and those with changing configurations are verified through a test-correlated analytical model. For payload racks, this analytical model is described in the rack's Acoustic Noise Control Plan (ANCP), which is reviewed by the AWG.

The payload rack's test-correlated analytical model consists of breaking down a rack's noise into source components that can be separated and recombined in different combinations. These components are defined in the design stages of the rack where each component is given an acoustic sub-allocation requirement. For example, the rack systems alone may be required to meet one requirement and each sub-rack payload may be given a separate sub-allocation (when combined, the total rack noise should meet the integrated rack requirements specified in SSP 57000). The components must be defined so that they can be tested individually, to verify compliance with their sub-allocation. Separating the sub-rack payloads also accommodates the modeling process.

If necessary, transfer functions are empirically or analytically developed so that the model is more accurate. For example, when a rear-breathing (i.e. fan inlets and outlets located on the rear) sub-rack payload is included, transfer functions are developed by measuring the payload in isolation and then again when mounted in the rack. The difference between these two sets of measurements define a transfer function which is used to correct the data of this and subsequent rear-breathing sub-rack payloads when predicting the noise of the specific rack.

Once the acoustic levels generated by each payload rack are known, the analysis of the module-level noise can be performed to compare with the complement level requirement. Currently, an integrated module-level analysis for intermittent noise is not performed. Each rack can operate under its own intermittent noise allocation without consideration of when the other racks are conducting intermittent operations. A method for analyzing the integrated module-level intermittent noise is under consideration.

The rack-level continuous noise data are combined, however, to predict the resulting payload complement noise levels for the entire module for a given Stage. These data are then combined with the module and GFE continuous noise, measured in ground tests or on-orbit, to obtain the final verification data for the integrated module for the Stage.

The PE&I Office predicts these payload complement continuous noise levels using the following procedure. A computational ray-tracing model, RayNOISE, is used to predict the noise levels at different locations in the module at each octave frequency band from 63 Hz to 8 kHz. The method predicts the noise at specified locations based on the noise emissions of individual payload racks, the geometry of the interior of the module, and the locations of the racks within the module. The method predicts the integrated noise based on both direct and reflected noise (reverberation) from each rack. Acoustic absorption factors are used in the model to determine the amount of acoustic energy that reflects from the interior module surfaces.

The verification data for each payload rack is converted from sound pressure levels, two feet from the loudest point on the rack, into a sound power level using basic acoustic theory. The rack is assumed to radiate this sound power into the interior module volume in a semi-hemispherical fashion. The individual contributions from each rack are then combined into a total sound power distribution and then converted back to sound pressure levels to give the total noise produced by the payload complement. This payload complement noise level should comply with the NC-48 requirement as discussed, above.

C. Integrated Module-Level Continuous Noise

The total integrated module-level continuous noise is determined by combining the payload complement noise levels with the module continuous noise levels and non-integrated GFE levels. These noise levels should comply with the curve created by combining NC-48 with NC-50 (Figure 1 and Table 1) in the absence of non-integrated GFE. The non-integrated GFE requirements are added in based on the number of continuous GFE items (there currently are none in the U. S. Lab). A sample plot of how the module plus integrated GFE levels are combined with the payload complement levels to determine the total integrated continuous noise levels in the U. S. Lab is shown in Figure 2. The requirements for each classification of noise source are also shown in Figure 2. If the implied requirement, (NC-50) + (NC-48) in this example, is not met then the situation is reviewed by the ISS AWG.

D. ISS Acoustic Working Group Review and Disposition

The ISS Acoustic Working Group is made up of representatives from several different disciplines that have an interest in or input to acoustic effects on the ISS crew. The Acoustics Office chairs the AWG and integrates and performs most of the technical acoustic work, along with the Payload Engineering & Integration Office acoustic specialists, and presents it to the rest of the AWG for discussion and disposition. The other disciplines also contribute in their technical area of expertise. Representation from these other areas include: 1) the Space Medicine and Health Care Systems Office, 2) the Astronaut Office, 3) the Safety, Reliability and Quality Assurance Office, 4) the Boeing Company Environments Team and 5) the International Space Station Program Office. Representatives from other areas are also included as required, for example the Marshall Space Flight Center acoustics specialists are often included in discussions.

The Acoustics Office and AWG review all aspects of the ISS acoustic environment, acoustic effects on the crew, and safety issues related to acoustics. It is preferred that hardware non-compliances be handled early in the process, before the CoFR process and AWG review. The Acoustics Office often acts as a resource to hardware developers in this regard and has worked to quiet many hardware items as discussed in Reference 1. Other organizations such as Marshall Space Flight Center's acoustics team also help hardware providers meet acoustic requirements.

In regards to Certification of Flight Readiness (CoFR), the AWG reviews the final expected continuous, intermittent and impulsive noise in each Module, as necessary. For most modules, where the acoustic environment is not expected to change much, the on-orbit data are reviewed and assessed. For the modules where new or additional hardware will be installed, in the U. S. Lab for example, the predicted noise and the method of prediction are reviewed. Safety Non-Compliance Reports (NCRs), and open or proposed waivers are also reviewed. Payload rack or complement waivers proceed in the form of Preliminary Interface Revision Notices (PIRNs). These PIRNs are submitted when a payload rack does not meet it's rack-level requirements, or when the payload complement does not meet the NC-48 continuous noise payload complement requirement. When waivers or NCRs are reviewed, the AWG discusses the data and information, and develops a disposition on whether or not the levels are acceptable. The chair of the AWG, the Acoustic Lead , has the ultimate responsibility for the hardware's acoustic compliance and the acoustic levels on the ISS.

In some cases, the AWG may recommend that hardware fixes be implemented. In other cases, operational constraints are placed on some payload racks to limit the duration of the noise that they create. In extreme cases, the AWG may recommend that the hardware not be manifested on the ISS until the acoustic levels are reduced or the situation is resolved.

The decision that is made on non-compliant hardware comes from consideration of many factors. These factors include not only the acoustic levels emitted by the hardware and the corresponding requirements, but other factors such as how many other hardware items are in operation during the time period, and how long the hardware under question will be operating on the ISS. There are many other possible factors that are hardware specific such as internal crew volumes, operational details, criticality of equipment, etc. It is assumed, based upon careful establishment of the requirements that if the hardware meets its requirements, it will be able to operate on ISS according to the requirements it meets. If it does not meet its requirements, it may still be able to operate on the ISS, but there may be constraints placed on it. Each item that does not meet requirements is reviewed for each ISS Stage and decisions on these items are made. In some cases hardware may be approved to operate on a given Stage, but not on another because of changing circumstances. To avoid operational constraints, it is recommended that hardware providers meet the acoustic requirements by considering noise emissions in the design and development of the hardware.

Once the AWG has dispositioned the acoustic levels for a given Stage, then this information is used as input into the Space and Life Sciences Directorate's CoFR process. As part of this process, open items, issues and concerns are addressed and then integrated into the ISS CoFR process. All waivers, exceptions and NCRs are implemented by the responsible organizations. For example, NCRs are processed through the Safety Review Panel. PIRNs are reviewed through the PIRN Review Team (PRT) and then approved through the ISS Program's Payload Control Board (PCB). All payload operational constraints are included in the PE&I Stage Analysis Report, which the Payload Operations Integration Center (POIC) uses to coordinate payload operations.

4. MISSION ACOUSTIC MONITORING AND MEASUREMENTS

The final step in the ISS noise control process is to make on-orbit acoustic measurements in order to establish and monitor the acoustic environment that the crew is exposed to, and to monitor directly, the noise exposure of each crewmember. These activities are referred to as acoustic monitoring and are included as part of the Environmental Health System as required by the Medical Operations and Requirements Document (MORD). Acoustic measurements are also made for several other reasons such as trouble-shooting a mission acoustics problem, supporting resolution of design issues, or performing acoustical experiments, for example. For more information on the other ISS on-orbit acoustic measurements, the reader is referred to Reference 5.

Two types of measurements are used to measure acoustic levels and exposure, sound level meter and audio (acoustic) dosimeter measurements. Sound Level Meter (SLM) measurements are made at specific measurement locations throughout the habitable volume of the ISS. The objective is to obtain accurate sound pressure level measurements of the continuous noise throughout the ISS for nominal operations. Care is taken that no intermittent noises (exercise, voice or ground communications, etc.) are occurring at the time of the measurements. Each data point is acquired over a 15 second time period, and the sound levels are measured in 1/3 octave frequency bands in the range from 33.5 Hz to 20 kHz. Octave bands are then calculated from this data to compare with requirements. These measurements are performed roughly every two months or whenever it is determined they are necessary.

Acoustic dosimeter measurements are also made approximately every two months. The purpose for these measurements is to measure the noise exposure to a crewmember or at a specific location, over an extended period of time. To satisfy both of these objectives, crew-worn and static dosimeter measurements are performed. The data for these measurements are acquired over a typical time period of 8, 16, or 24 hours, so that the measurements include all of the types of noise created on the ISS. The data from these measurements are quantified as equivalent A-weighted overall sound pressure levels, in dBA re 20 μPa, over the specified period of time.

For the crew-worn acoustic dosimetry measurements, a dosimeter is worn by a crewperson on their belt with the microphone clipped on their lapel. The dosimeter is donned in the morning and is worn for approximately 16 hours throughout a nominal workday. The measurement is recorded and the dosimeter is reset. The dosimeter is then worn while the crewmember is in their bunk for approximately 8 hours.

For static acoustic dosimeter measurements, the dosimeters are deployed at specified locations in the ISS. They are usually mounted to wall panels or some other surface. Measurements are performed over a specified time period. Since there are three dosimeters on board ISS at any one time, there are usually three static dosimeter measurements made approximately every two months.

Data from the above SLM and acoustic dosimeter measurements are presented and discussed in Reference 1. For more information on these ISS acoustic monitoring measurements, including the type of hardware used, information on training, procedures, scheduling etc., please refer to Reference 5.

5. CONCLUDING REMARKS

The present paper describes the process used to control the acoustic noise environment aboard the International Space Station in order to achieve safe living and working conditions for the ISS crew. This noise environment is created by different types of flight hardware including modules, integrated GFE, non-integrated GFE, and payloads.

In general, the acoustic requirement for modules with integrated GFE is NC-50, and for payload complements in a module is NC-48. The acoustic requirements for payload racks and non-integrated GFE include intermittent and continuous requirements. The continuous noise requirement for payload racks and non-integrated GFE is NC-40 measured at a 0.6-meter distance. Payload sub-rack requirements are determined by the rack integrator in order to meet the rack-level requirements.

Consulting and noise control support provided by NASA and the Acoustics Office to help hardware developers meet the acoustic requirements is out of the scope of the present paper. For more information on this topic, the reader is referred to the companion paper by Goodman.

Verification and certification that flight hardware meets the acoustic requirements is performed either by test or by using a test-correlated analytical model. Different models are used for payload rack, payload complement, and total integrated module acoustic verifications.

The Acoustic Working Group, an advisory committee made up of many disciplines that have an input or interest in the ISS acoustic environment, reviews any non-compliance with acoustic requirements. Actions that can be taken by the AWG include requiring remedial actions to quiet hardware, applying operational constraints to limit hardware operations, or de-manifesting hardware, among other options. To avoid these situations it is recommended that hardware developers work towards meeting acoustic requirements by including noise control principles and methods in the design and development of their hardware.

6. REFERENCES

[1]Jerry R. Goodman, "International Space Station Acoustics," *NOISE-CON,* Conf (2003).

[2]"Leo L. Beranek, "Criteria for noise and vibration in communities, buildings, and vehicles," Chap. 17 in *Noise and Vibration Control Engineering-Principles and Applications,* edited by Leo L. Beranek and Istvan L. Ver (Wiley, New York, 1992).

[3]*System Specification for the International Space Station,* Space Station Program Document SSP 41000R: March 2000.

[4]ISS Acoustic Requirements and Testing Document for ISS Non-Integrated Equipment, Johnson Space Center Document JSC 28322: March 1999.

[5]Gregory D. Pilkinton, "ISS Acoustics Mission Support," *NOISE-CON,* Conf (2003).

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Table 1. ISS continuous noise requirements for various classes of hardware.

Octave Band Frequency Hz	Module NC-50 (SSP 41000)	Russian Segment (SSP 50094)	Payload Compliment NC-48 (SSP 57011)	Payload Rack and Non-Int GFE NC-40 (SSP 57000)	Isle-Mounted Payload NC-34* (SSP 57000)	EXPRESS sub-rack mod. NC-32 (SSP 52000)	Module + Payload Complement NC-48 + NC-50 (implicite requirement)
63	71	79	69.4	64	59	58	73.3
125	64	70	62.4	56	52	50	66.3
250	58	63	56.4	50	45	42	60.3
500	54	58	52	45	39	38	56.1
1K	51	55	49	41	35	32	53.1
2K	49	52	47	39	33	32	51.1
4K	48	50	46	38	32	32	50.1
8K	47	49	45	37	31	31	49.1

*NC-34 requirement goes into effect for Flight UF-3 and subsequent flights.

Table 2. ISS intermittent noise requirements for non-integrated GFE and payload racks.

Maximum Noise Duration	A-weighted Overall Sound Pressure Level dBA
8 Hours	49
7 Hours	50
6 Hours	51
5 Hours	52
4.5 Hours*	53
4 Hours	54
3.5 Hours*	55
3 Hours	57
2.5 Hours*	58
2 Hours	60
1.5 Hours*	62
1 Hour	65
30 Minutes	69
15 Minutes	72
5 Minutes	76
2 Minutes	78
1 Minute	79
Not Allowed	80

*These half-hour increments only apply to payloads.

Figure 1. ISS continuous noise requirements for various classes of hardware.

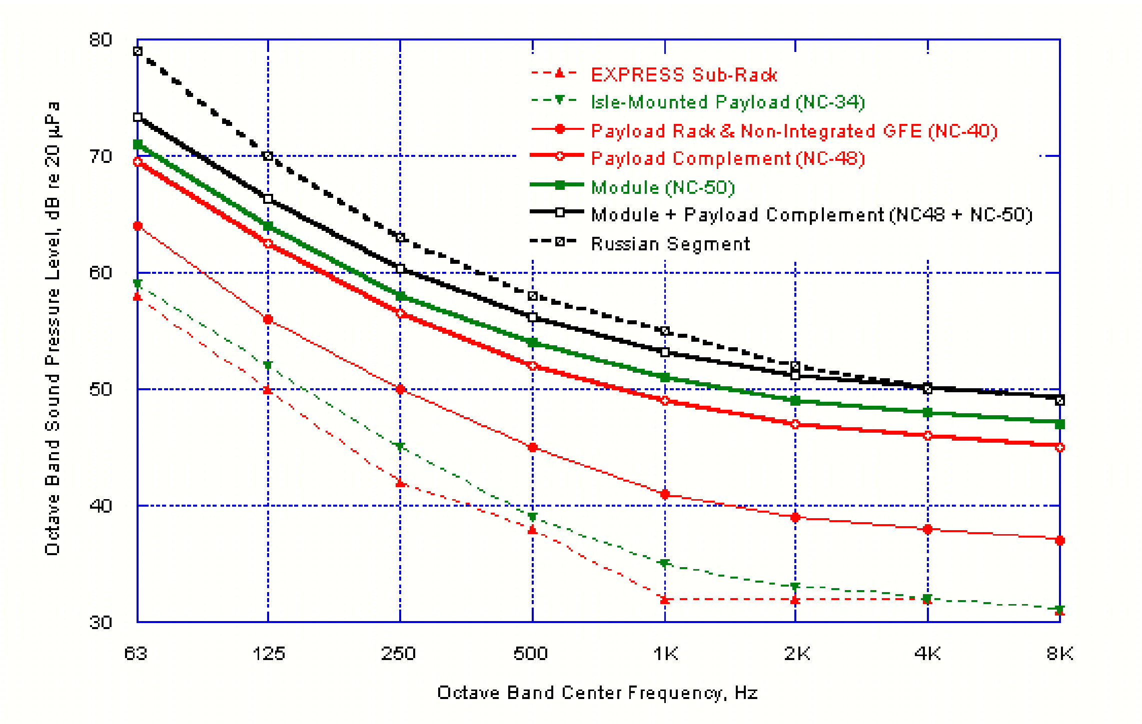

Figure 2. Example of integrated U. S. Lab acoustic prediction from module plus GFE and payload noise sources. Corresponding requirement levels are also shown.